PRELIMINARY PROPOSAL FOR FY 2005 FUNDING

Title: Estimates of fish, spill and sluiceway passage efficiencies of radio-tagged juvenile salmonids at The Dalles Dam in 2005.

Study Code: SPE-P-00-8

This proposal addresses Objectives 3 and 4 under the study code SPE-P-00-8 as identified in the one-page AFEP research summary entitled "Juvenile salmonid survival studies at The Dalles Dam".

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PROJECT SUMMARY

RESEARCH GOALS

The goal of this study is to determine the passage locations and approach patterns of juvenile salmonids at The Dalles Dam. This will provide an evaluation of passage with a new spill wall as well as assist in planning decisions relative to a behavioral guidance structure or other surface flow bypass system. This will be accomplished by calculating the overall proportion of radio-tagged fish passing the powerhouse, spillway and sluiceway (wall evaluation) and by comparing estimates of fish, spill and sluiceway passage efficiencies of fish with different approach patterns (approach evaluation).

STUDY OBJECTIVES

Objective 1. Estimate fish, spillway and sluiceway passage efficiencies of radio-tagged fish at The Dalles Dam (AFEP research summary SPE-P-00-8 Objective 3).

The purposes of this objective will be to determine the passage metrics as a continued evaluation of the new spill wall between spill bays 6 and 7. Species-specific estimates of FPE, SPE and SLPE of radio-tagged juvenile salmonids during BIOP spill levels will be determined and alternative sluiceway skimmer gate operations and their effect on SPE will be evaluated. The FPE is the proportion of juvenile salmonids passing the dam via sluiceway and spillway (all non-turbine routes), SPE is defined as the proportion of tagged fish passing via the spillway, and SLPE is the proportion of juvenile salmonids passing via the sluiceway.

Objective 2. Determine approach pattern and forebay residence times of radio-tagged fish at The Dalles Dam (AFEP research summary SPE-P-00-8 Objective 4).

In-river telemetry arrays will be used to identify the river area of approach and subsequent dam passage of radio-tagged fish released near John Day Dam. The purpose of this objective is to collect approach and passage information to support future decisions about the need and placement of a behavioral guidance structure or other surface bypass system proposed for installation at The Dalles Dam.

Fish used for this study will be released at or near John Day Dam under AFEP Study Code SPE-P-00-8 "Juvenile salmonid survival studies at The Dalles Dam". Design of that study has not been finalized, but it is reasonable to expect approximately 2250 yearling Chinook salmon or juvenile steelhead and 2000 subyearling Chinook salmon to be tagged and released from the John Day Dam tailrace under that study code. The spring species will be determined through regional forums. These releases can be expected to result in approximately 1800 yearling Chinook salmon (*Oncorhynchus tshawytscha*) or juvenile steelhead (*Oncorhynchus mykiss)* and 1600 subyearling Chinook salmon detected as they pass The Dalles Dam (assumes a conservative 80% detection probability).

RELEVANCE TO THE BIOLOGICAL OPINION

This study addresses the 2000 Biological Opinion RPA numbers 69 and 86 (NMFS 2000). These actions direct studies of decreased turbine passage and increased sluiceway and spillway passage at The Dalles Dam.

PROJECT DESCRIPTION

BACKGROUND AND JUSTIFICATION

A Supplemental Biological Opinion issued by the National Marine Fisheries Service (NMFS) recommended that spill volumes at dams on the Columbia and Snake rivers be maximized to increase juvenile salmonid (*Oncorhynchus* spp.) survival without exceeding the current total dissolved gas cap levels or other project-specific limitations (NMFS 1998). While there is a consensus that survival is greater for fish passing via spillways than most other routes of dam passage, questions regarding the effectiveness of different spill patterns and other passage scenarios remain (Dawley et al. 1998).

Generally, a 1:1 ratio is assumed between the percent of total fish that pass through the spillway and the percent of river flow passing through the spillway for most Columbia and Snake river dams (Whitney et al. 1997). However, Whitney et al. (1997) found that spill effectiveness was greater than the 1:1 ratio at The Dalles Dam and that a spill volume of 31% of total river flow was needed to achieve 80% FPE for spring and summer migrants. Estimates of FPE based on radio telemetry ranged from 73.5 to 95.3% in 1999, depending on spill level (30 or 64%), spill pattern, and species (Hansel et al. 2000). The FPE of both species are lower at night than during the day, with as much as 26% of yearling Chinook salmon and 18% of juvenile steelhead passing through the turbines at night, compared to 10 and 6%, respectively, during the day (2000 radio telemetry data).

Recent measures to reduce passage mortality and turbine entrainment of juvenile salmonids at The Dalles Dam have focused on increasing spill passage with both operational and structural methods. However, the turbine intake occlusion plates tested in 2001 and 2002 did not achieve the desired results, so other structural methods are being considered (e.g., a behavioral guidance structure). Currently, an operation of 40% spill dispersed using the "juvenile" spill pattern is used, but studies have indicated low survival of fish passed through some areas of the spillway (Normandeau Associates 2003). Research indicated the areas resulting in low survival also resulted in extended times in the stilling basin due to a lateral flow gradient caused by the juvenile spill pattern (Hansel et al. 2002), so a wall dividing the spillway was installed between bays 6 and 7 prior to the 2004 migration season. The addition of this wall was expected to improve survival of spillway-passing fish and is consistent with plans to add other structural measures to divert fish from the powerhouse to this route as a further method of reducing passage mortality and turbine entrainment.

The U.S. Army Corps of Engineers (COE) has proposed studies in 2005 to examine the passage of juvenile salmonids through The Dalles Dam under BIOP spill. These studies will be designed to determine the proportions of fish population passing the turbines, sluiceway and spillway as a continued evaluation of the new spill wall, as well as to discern the approach pattern of fish to aid in design of a structural fish guidance device at the powerhouse.

Figure 1. Aerial photo of The Dalles Dam spillway with the new spill pattern based on the wall between spill bays 6 and 7.

PROJECT OVERVIEW

The U.S. Geological Survey has studied juvenile salmonid behavior in dam forebay environments since the early 1990s. Recently, our work has been focused primarily on assessing surface bypass/collection concepts at John Day, The Dalles, Bonneville, and Lower Granite dams. As part of this research, we have estimated passage of radio-tagged fish by determining the area where fish were last detected by fixed receiving equipment located on the forebay and tailrace periphery. The validity of this method for determining passage routes was verified by manually detecting passage location of fish and then comparing these records with those recorded by fixed receiving equipment. To accurately determine passage location of radio-tagged fish we propose to continue the use of similar monitoring techniques presented in our earlier reports of research at John Day, The Dalles, and Bonneville dams (e.g., Sheer et al. 1996, Holmberg et al. 1998, Hensleigh et al. 1999, Hansel et al. 2000, Beeman et al. 2003.) As in 2000-2003, we propose to monitor specific passage routes through the dam using a multi-protocol-integrated-telemetry-acquisition systems (MITAS) and underwater antennas along the powerhouse, spillway and sluiceway. The MITAS system was designed to take advantage of the

increasing power and decreasing costs of personal computers to monitor radio tags in a more cost-effective manner. Aerial antennas with conventional-scanning telemetry receivers will be used in the forebay and tailrace.

Aerial antennas will be used to monitor fish movements within approximately 60 m of the forebay and tailrace sides of the dam. Current aerial antenna installations in the forebay include in-river arrays located upstream of the east end of the powerhouse and near the west end of the powerhouse, as well as antennas with complete coverage of the powerhouse, non-overflow wall and spillway. Tailrace aerial antennas are located with complete coverage of the powerhouse and spillway as well as several locations on the Oregon shore near the powerhouse and near the south spillway adult ladder entrance. Fifty-three 4-element Yagi aerial antennas and 11 corner-reflector antennas (at the spillway tailrace) will be used.

The in-river detection arrays will be used to determine approach patterns of tagged fish in preparation for possible guidance screen implementation. The in-river arrays will provide up to four horizontal regions each. The FPE, SPE and SLPE of fish detected passing each region as well as the location of dam passage can be determined. These arrays were first used at The Dalles Dam in 2003. Each of the arrays consists of aerial antenna stations at each shoreline as well as one deployed from a floating platform anchored near the middle of the river. The in-river station will have aerial antenna (s) pointed toward each shore. The data from each array will be used to divide the detected fish into one of up to four regions, including Washington shore to midpoint between shore and in-river station, in-river station to midpoint between it and Washington shore, and the two complimentary regions on the Oregon side of the river. The number of regions may be fewer, depending on the coverage of each station. The final regions will be determined after the equipment is deployed. The approximate locations of the arrays will be at the upstream end of the earthen dam and near Main Unit 18 as in 2003 and 2004.

Underwater dipole antennas at the powerhouse and spillway will be used to monitor fish presence within approximately 10 m of the structures (Beeman et al. 2004). Four underwater antennas will be used to monitor fish within each spill bay; two antennas on each pier nose at elevations 121 ft msl (39 ft depth) and 141 ft (19 ft depth) at normal pool elevation of 160 ft msl (the ogee crest is elevation 121 ft msl). There are 88 underwater antennas installed at the spillway forebay. Underwater antennas at the powerhouse are located at several elevations along the pier noses between each main unit (81 antennas total). There are antennas at elevations 140, 120 and 100 ft msl on the pier noses between main units 22 thru the downstream end of Fish Unit 1.

CURRENT STATUS

Assessments of juvenile salmonid passage at The Dalles Dam using radio-telemetry were conducted each year from 1999 through 2004. Results from these studies have indicated the juvenile spill pattern results in a greater FPE than the adult pattern, that 40% spill results in FPE similar to 64% spill, and, in 2002, that bulk loading the powerhouse main units at the west end may result in lower FPE than standard operation (Table 1). Median forebay residence times are typically less than 2 h. Tests of juvenile fish passage with and without turbine intake occlusion

devices were conducted in 2001 and 2002, but the devices did not meet regional expectations. Data from a study of fish approach and passage in 2003 showed a large proportion of both yearling and subyearling Chinook salmon approaching the dam near the powerhouse. While passage by approach path differed significantly between northerly and southerly approaching fish, the overall passage efficiencies are similar to past results under similar spill conditions. The passage efficiency data from 2002 was atypically low due perhaps to the aforementioned bulk loading of the powerhouse to test the Sluiceway Guidance Improvement Devices.

Detections of radio-tagged juvenile salmonids have been high at TDA since we began using this method for FPE estimates in 1999. Detections of fish released at Rock Creek and those released in the tailrace of John Day Dam (JDA) have typically been greater than 80%, and have been as high as 98.6% for fish released in the John Day tailrace.

OBJECTIVES AND METHODOLOGY

Objective 1. Estimate fish, spillway and sluiceway passage efficiencies of radio-tagged fish at The Dalles Dam (AFEP research summary SPE-P-00-8 Objective 3).

Rationale

The COE is in the process of evaluating various scenarios to maximize juvenile fish passage at The Dalles Dam. The purpose of this Objective is to evaluate fish passage locations relative to the new wall installed between spill bays 6 and 7 prior to the 2004 migration season. This wall was designed to reduce lateral entrainment and long stilling basin residence times created by the juvenile spill pattern in the past. Thus, the current operational plan is to pass 40% spill through spill bays 1 through 6, which will likely alter the proportions of fish population passing the powerhouse, sluiceway and spillway from previous operations at TDA.

The seasonal timing of releases of radio-tagged fish is dependent on when the fish arrive and when they are large enough to accommodate the radio transmitter. Minimum fish sizes are 21.5 g (approximately 130 mm) for yearling Chinook salmon and juvenile steelhead (1.40 g radio transmitter weight in air) and 13 g (approximately 110 mm) for subyearling Chinook salmon (0.85 g radio transmitter weight in air). The minimum fish weights insure that the tag weight in air does not exceed 6.5% of the fish weight in air. The dates these criteria have been met in the

Table 1. Passage metrics determined from USGS radio-telemetry studies at The Dalles Dam

during 1999, 2000, 2002, and 2003.

Metric	Percent spill	Yearling Chinook	Juvenile Steelhead	Subyearling Chinook
FPE	30 (1999)	73%	91%	N/A
	40 (2000)	85%	91%	88%
	40 (2002)	70%	90%	63%
	40 (2003)	88%	N/A	89%
	64 (1999)	91%	95%	N/A
SPE	30 (1999)	51%	66%	N/A
	40 (2000)	79%	85%	77%
	40 (2002)	60%	76%	55%
	40 (2003)	71%	N/A	77%
	64 (1999)	79%	86%	N/A
SLPE	30 (1999)	22%	25%	N/A
	40 (2000)	6%	6%	11%
	40 (2002)	10%	14%	8%
	40 (2003)	17%	N/A	12%
	64 (1999)	12%	9%	N/A

past several years at John Day Dam have been between approximately 15 April and 05 June for yearling Chinook salmon and juvenile steelhead and 06 June and 08 August for subyearling Chinook salmon. Spilling outside these general time windows for the purpose of this study is not required. In the 2003 study, yearling Chinook salmon were tagged and released between the 5th and 98th percentile of their passage at the dam. The tagging process often has to be delayed to allow the minimum size criteria to be met for subyearling Chinook salmon collected at John Day Dam; in the 2003 study, subyearling Chinook salmon were tagged and released between the 32nd and 82nd percentile of their passage at the dam.

Pulse-coded transmitters operating at frequencies between 162 and 174 MHz will be used to allow each fish to be recognized. Transmitters for yearling Chinook or juvenile steelhead will be no larger than 7.3 mm in diameter x 18.0 mm in length and weigh 1.40 g in air (Lotek Wireless model 3KM). Transmitters for subyearling Chinook will be no larger than 6.3 mm x 4.5 mm x 14.5 mm in length and weigh 0.85 g in air (Lotek Wireless model NTC-3-1). Transmitters will be gastrically implanted using the methods of Adams et al. (1998). Following tagging, fish will be held in tanks for 20 to 28 h to allow fish time to recover from the procedure. After the holding period, the tanks will be checked for mortalities and fish well be transported to

the release sites. Any regurgitated tags will be removed from the containers immediately prior to release.

We will estimate fish passage proportions through the powerhouse, sluiceway and spillway during 40% spill at TDA in the spring and summer of 2005. We propose to use yearling Chinook salmon or juvenile steelhead in the spring and subyearling Chinook salmon in the summer.

If survival studies based on radio-telemetry at TDA are conducted and approximately 2250 yearling Chinook salmon or juvenile steelhead and 2000 subyearling Chinook salmon are released (as in 2003), we would expect 2250 x 0.8 = 1800 spring detections and 2000 x 0.8 = 1600 summer detections at The Dalles Dam. These would be sufficient for a 95% confidence interval around a FPE, SPE or SLPE estimate from yearling Chinook salmon or juvenile steelhead of ± 1.8% and subyearling Chinook salmon of ± 2.0% if the passage estimates are ≥ 0.8 or ≤ 0.2, which encompasses likely estimates of FPE, SPE and SLPE (Moore and McCabe 1989; Figure 1). Aerial antennas in the tailrace will be used to estimate the detection efficiencies of the forebay aerial and underwater antenna arrays as described in Lowther and Skalski (1997).

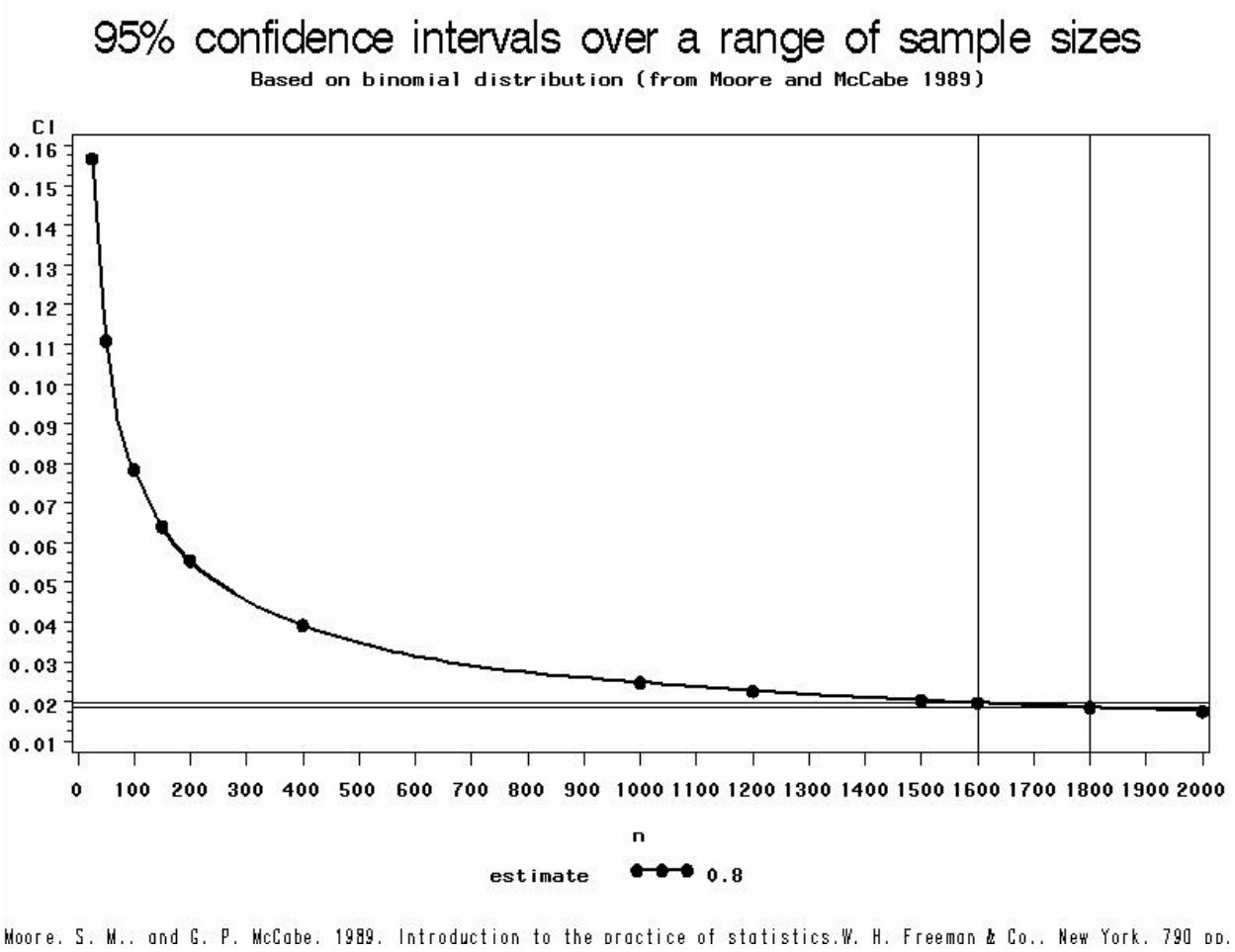

Figure 2. Estimated 95% confidence intervals over a range of sample sizes based on a binomial distribution for a proportion equal to 0.8 (from Moore and McCabe 1989).

Task 1.1: Set up and test fixed receiving equipment in forebay and tailrace areas of The Dalles Dam.

Activity 1.1.1.
Configure aerial and underwater detection arrays at TDA. This schedule assumes antennas and cables can be left in place from 2004 studies, but electronic devices will need to be reinstalled and adjusted.

Schedule: January-April, 2005.

Activity 1.1.2.

Test system performance by drifting transmitters through antenna arrays to assess and improve antenna coverage. This will be done to ensure proper system operation.

Schedule: January-April, 2005.

Task 1.2: Monitor the performance of receiving equipment with diagnostic checks and download equipment at least twice weekly.

Activity 1.2.1.

Perform diagnostic checks on receiving equipment 3 to 7 times per week.

Schedule: April-August, 2005.

Activity 1.2.2.

Download telemetry receivers and MITAS system 3 to 7 times per week.

Schedule: April-August, 2005.

Task 1.3: Proof and summarize data collected in the form of in-season data summaries, and interim and annual reports.

Calculations of FPE, SPE and SLPE are based on fish detected by the telemetry equipment. These detections will be adjusted by the detection efficiencies of arrays at each route of passage to arrive at the most accurate estimates of passage.

Schedule: May 2004-March 31, 2006.

Objective 2. Determine approach pattern and forebay residence times of radio-tagged fish at The Dalles Dam (AFEP research summary SPE-P-00-8 Objective 4).

Rationale

The COE is in the process of evaluating the possible use of a behavioral guidance structure to increase non-turbine juvenile fish passage at TDA. This is based on the success of such a device at Lower Granite Dam and the high cost estimates of other juvenile fish passage

improvements at TDA. The approach paths of juvenile salmonids will need to be determined prior to evaluating the use of such a device at The Dalles Dam as well as to design the device if its use is authorized. A study to determine vertical and horizontal distributions of juvenile salmonids via 3-D hydroacoustics was proposed by Cash et al. (2003) and another proposal is expected for 2005. We propose to determine the horizontal distributions of radio-tagged juvenile salmonids at the two array locations used in 2003 and 2004 as well as provide estimates of forebay residence times. This approach is feasible and can be completed at little additional cost, since several thousand radio-tagged fish used for survival and FPE assessment will be migrating past TDA. The locations of detected fish at each array could be divided into up to four horizontal regions, depending on the antenna coverage measured during deployment. These regions would be the Washington shore to midpoint between shore and in-river station, in-river station to midpoint between it and Washington shore, and the two complimentary regions on the Oregon side of the river.

Task 2.1: Install in-river and shore-based aerial telemetry equipment at each of three array locations. Aerial antennas will be used to create two in-river detection arrays to determine approach patterns of tagged fish in preparation for possible guidance screen implementation.

Activity 2.1.1.

Reinstall floating platforms at two locations. The approximate locations of the arrays will be at the upstream end of the earthen dam and near Main Unit 18 (as in 2003 and 2004). The floating platforms will be anchored near the mid-point of the Columbia River at each site as they were in 2004.

Schedule: February-April, 2005.

Activity 2.1.2. Download data from in-river and shore-based stations.

Data from in-river stations will be downloaded using radio-modems several times per week during passage of tagged fish. Data from the shore-based stations will be downloaded on a similar schedule.

Schedule: April-August, 2005.

FACILITIES AND EQUIPMENT

Much of the equipment we will use was purchased by the COE during earlier studies. We do not foresee the need for additional non-expendable equipment for this study in 2005. All transmitters are being purchased by the COE under separate contract.

The Columbia River Research Laboratory, a field station of the U.S. Geological Survey's Western Fisheries Research Center, is located in Cook, Washington along the Columbia River. The facility is approximately 60 miles east of Portland, Oregon and is located on the grounds of the U.S. Fish and Wildlife Service's Willard National Fish Hatchery. The laboratory has wet lab and dry lab facilities, office space, and a mechanical shop. The electrical system is connected to backup generators for emergency use during power outages. The laboratory has a fleet of approximately 30 vessels ranging from 18 to 30 feet in length that are capable of performing a variety of tasks. Staff at the facility are involved in telemetry studies using radio and acoustic transmitters and receivers. The office has exceptional computational capabilities and a T-1 line connecting to the Internet. Staff use a variety of graphical and analytical software, and geographic information systems including Arc/Info and ArcView to facilitate data summarizations and presentations.

IMPACTS

Impacts to other researchers

Some potential impact on other ongoing research activities is possible, since radio telemetry is widely used throughout the basin in a variety of fish behavior studies. As in previous years, the USGS will alter the radio frequencies they use such that no other fish will be released on these frequencies in the Columbia or Snake rivers. We will coordinate radio frequencies used with other USGS researchers to minimize conflicts. Research efforts will be coordinated with personnel from other groups performing research at The Dalles Dam.

Impacts to The Dalles Dam project

Equipment installation may begin as early as January or February 2005 with completion by the end of April 2005. Any in-water work within the dam boat restricted zones will be completed prior to the initiation of BIOP spill. We anticipate that the need for project assistance should be small, as our current equipment was designed so that we can install it ourselves.

The placement of aerial and underwater antennas will require project coordination and support unless a significant portion of the equipment can remain in place between the 2004 and 2005 migration seasons. In addition, underwater installation pipes at the spillway may need repair and project support will be required if this is the case. The placement of antennas in the forebay will be similar to locations we have used at the project before; minor changes may be made after thorough analysis of data collected in 2004.

We will require project coordination (i.e., BRZ access) to install the in-river telemetry station within the forebay BRZ. We will coordinate the timing of this task with similar work proposed by other research groups to avoid duplication of effort.

We will require access to 110-volt power sources at most fixed receiving stations. We will require access to the juvenile bypass facility at John Day Dam to tag, hold, and release radio-tagged fish.

Space to house the MITAS system will be required (approximately March thru September) at the dam. This room located within the non-overflow wall used for this purpose since 2000 would be most appropriate, as existing wiring is run to this location.

COLLABORATIVE ARRANGEMENTS AND SUB-CONTRACTORS

We currently have several other research studies proposed under this and other AFEP project codes. These include project, turbine and sluiceway survival under this study code (SPE-P-00-8) and Evaluation of the John Day Dam spillway as a juvenile passage route (SPE-P-00-7). The SPE/FPE objective at The Dalles Dam will not impact the other studies, but will enhance their data, or benefit from fish released for their purposes.

The COE will benefit from FPE studies based on radio telemetry and hydroacoustics if both are conducted. The radio telemetry method results are species-specific, include approach and residence time, and gather data from known individuals. Limitations of radio telemetry include possible behavioral effects from tag implantation and presence, truncated seasons due to fish size and water temperatures, and low sample size relative to some other methods. Fixed hydroacoustic information provides data from large numbers of fish, which enables this data to be analyzed to examine passage in small increments of time and space, but cannot be used to determine species-specific information and cannot generally provide approach pattern and similar behavioral data.

We will require the engineering services of Grant Systems Engineering (the manufacturer of the MITAS system) to help balance and troubleshoot the MITAS systems. A dive contract will be required to inspect several underwater antennas prior to the spill season.

List of Key Personnel and Project Duties

Alec Maule	Project Leader
John Beeman	Team Leader

Ben Hausmann	Principal Investigator
Steve Juhnke	Tagging Coordinator
Hal Hansel	Data Analysis Coordinator
Philip Haner	Electronics Technician

TECHNOLOGY TRANSFER

Results from this study will be disseminated in the form of preliminary reports, annual reports of research, oral presentations and briefings, and peer-reviewed journal publications. Preliminary data for the spring and summer out migration periods will be available September 1 and October 1, 2005, respectively. The draft annual reports of research will be submitted to the COE by December 31, 2005 (spring) and January 30, 2006 (summer). Comments from the COE will be accepted for 45 d from receipt of the draft final reports, after which the USGS will provide a final report to the COE or any interested party within 60 d.

REFERENCES CITED

Adams, N. S., D. W. Rondorf, S. D. Evans, J. E. Kelly, and R. W. Perry. 1998. Effects of surgically and gastrically implanted radio transmitters on swimming performance and predator avoidance of juvenile Chinook salmon (Oncorhynchus tshawytscha). Canadian Journal of Fisheries and Aquatic Sciences 55:781-787.

Beeman, J. W., C. Grant and P. V Haner. 2004. Comparison of three underwater antennas for use in radio telemetry. North American Journal of Fisheries Management 24:275-281.

Beeman, J. W., H. C. Hansel, P. H. Haner, and J. Hardiman. In Review. Estimates of fish passage efficiency of radio-tagged juvenile steelhead and yearling Chinook salmon at The Dalles Dam, 2000: annual report of research. Prepared by U. S. Geological Survey, Cook, Washington for U. S. Army Corps of Engineers, Portland, Oregon, USA.

Beeman, J. W., H C. Hansel, P. V. Haner, K. Daniel, and J. Hardiman. 2003. Estimates of fish and spill passage efficiency of radio-tagged juvenile steelhead and yearling and subyearling Chinook salmon at John Day Dam in 2000. Prepared by U. S. Geological Survey, Cook, Washington for U. S. Army Corps of Engineers, Portland, Oregon, USA.

Beeman, J. W., H. C. Hansel and J. Phelps. 2002. Estimate fish, spill and sluiceway passage efficiencies of radio-tagged juvenile salmonids relative to operation of J-design occlusion pates at The Dalles Dam in 2002: Preliminary report of research during 2002. Prepared by U. S. Geological Survey, Cook, Washington for U. S. Army Corps of Engineers, Portland, Oregon, USA.

Cash, K. M., N.S. Adams, D. W. Rondorf, D. M. Faber, M. A. Weiland, and T. J. Carlson. 2003. Three-dimensional behavior and passage of juvenile salmonids at The Dalles Dam, 2004. Research proposal for 2004 project year, date of submission December 2003. Prepared by U. S. Geological Survey, Cook, Washington for the U. S. Army Corps of Engineers, Portland, Oregon, USA.

Hansel, H. C., J. W. Beeman, T. D. Counihan, B. L. Liedtke, M. S. Novick, and J. M. Plumb. In Review. Estimates of fish passage efficiency of radio-tagged juvenile steelhead and yearling Chinook salmon at John Day Dam, 1999: annual report of research. Prepared by U. S. Geological Survey, Cook, Washington for U. S. Army Corps of Engineers, Portland, Oregon, USA.

Hansel, H. C., J. W. Beeman, K. Daniel, A. Daniel, and P. Haner. 2002. Estimating stilling basin residence time, lateral distribution of passage, and relative survival of juvenile Chinook salmon passing through the spillway of The Dalles Dam in 2002: interim report dated August 7, 2002. Prepared by U. S. Geological Survey, Cook, Washington for U. S. Army Corps of Engineers, Portland, Oregon, USA.

Hensleigh, J. E., R. S. Shively, H. C. Hansel, J. M. Hardiman, G. S. Holmberg, B. D. Liedtke, T. M. Martinelli,

R. E. Wardell, R. H. Wertheimer, and T. P. Poe. 1999. Movement, distribution, and behavior of radio-tagged juvenile Chinook salmon and steelhead in John Day, The Dalles, and Bonneville dam forebays, 1997: annual report of research. Prepared by U. S. Geological Survey, Cook, Washington for U. S. Army Corps of Engineers, Portland, Oregon, USA.

Holmberg, G. S., R. S. Shively, H. C. Hansel, T. L. Martinelli, M. B. Sheer, J. M. Hardiman, B. D. Liedtke, L. S. Blythe, and T. P. Poe. 1998. Movement, distribution, and behavior of radio-tagged juvenile Chinook salmon in John Day, The Dalles, and Bonneville Dam Forebays, 1996. Annual Report of Research to the U.S. Army Corps of Engineers, Portland District, Portland, Oregon, USA.

Lowther, A. B., and J. Skalski. 1997. The design and analysis of salmonid tagging studies in the Columbia Basin, Volume VIII. A new model for estimating survival probabilities and randomization from a release-recapture study of fall Chinook salmon (Oncorhynchus tshawytscha) smolts in the Snake River. Prepared by The University of Washington School of Fisheries, Seattle, Washington USA for the U.S. Department of Energy, Bonneville Power Administration, Portland, Oregon, USA, contract DE-BI79-90BP02341.

Moore, S. M., and G. P. McCabe. 1989. Introduction to the practice of statistics. W. H. Freeman & Co., New York. 790 pp.

NMFS (National Marine Fisheries Service). 1995. Endangered Species Act - Section 7 Consultation: Biological Opinion. Prepared by the National Marine Fisheries Service, Northwest Region, Seattle, Washington, USA.

NMFS (National Marine Fisheries Service). 1998. Endangered Species Act - Section 7 Consultation: Supplemental Biological Opinion. Prepared by the National Marine Fisheries Service, Northwest Region, Seattle, Washington, USA.

NMFS (National Marine Fisheries Service). 2000. Endangered Species Act - Section 7 Consultation: Biological Opinion December 21, 2000. Prepared by the National Marine Fisheries Service, Northwest Region, Seattle, Washington, USA.

Normandeau Associates. 2003. Estimated direct mortality and injury rate of juvenile salmonids in passage through The Dalles Dam spillway, Columbia River in spring and summer 2002. Report prepared by Normandeau Associates Environmental consultants for U. S. Army Corps of Engineers, Portland, Oregon, USA, contract DACW68-02-D-002.

Sheer, M. B., G. S. Holmberg, R. S. Shively, T. P. King, C. N. Frost, H. C. Hansel, T. M. Martinelli, and T. P. Poe. 1997. Movement, distribution, and passage behavior of radio-tagged juvenile Chinook salmon in John Day and The Dalles Dam forebays, 1995. Annual report of research, U.S. Army Corps of Engineers, Portland District, Portland, Oregon, USA.

Whitney, R. R., L. D. Calvin, M. W. Erho, Jr., C. C. Coutant. 1997. Downstream passage for salmon at hydroelectric projects in the Columbia River Basin: development, installation, and evaluation. Prepared

for the Northwest Power Planning Council, Portland, Oregon, USA. #97-15.